

1 PRE-PRINT—DRAFT PRIOR TO PEER REVIEW

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3 **Shark conservation risks associated with the use of shark liver oil in SARS-CoV-2 vaccine**  
4 **development**

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12  
13 **Abstract:** The COVID-19 pandemic may create new demand for wildlife-generated products for  
14 human health, including a shark-derived ingredient used in some vaccines. Adjuvants are a  
15 vaccine component that increases efficacy, and some adjuvants contain squalene, a natural  
16 compound derived from shark liver oil which is found most abundantly in deep-sea sharks. In  
17 recent decades, there has been growing conservation concern associated with the sustainability of  
18 many shark fisheries. The need for a potentially massive number of adjuvant-containing SARS-  
19 CoV-2 vaccines may increase global demand for shark-derived squalene, with possible  
20 consequences for shark conservation, especially of vulnerable and understudied deep-sea species.  
21 A shift to non-animal-derived sources of squalene, which are similar in cost and identical in  
22 effectiveness, or an emphasis on increasing traceability and sustainability of shark-derived  
23 squalene from existing well-managed fisheries, could better support conservation and public  
24 health goals.

25  
26 **Keywords:** Squalene, COVID-19, SARS-CoV-2, Shark, Liver oil, Vaccines

27  
28 **1. Introduction**

29  
30 Shark populations have historically been exploited for meat, fins, leather, and products derived  
31 from their liver oil, including vitamin A and additives to topical cosmetic formulas and lotions  
32 (Dent and Clarke, 2015; Lozano-Grande et al., 2018). Some historic shark liver oil fisheries have  
33 been associated with intense, short-lived periods of exploitation contributing to stock collapses  
34 (Stevens et al., 2000; Kyne and Simpfendorfer, 2007; Anderson and Waheed, 1999; Ali and  
35 Sinan, 2014). Sharks, particularly deep-sea species, tend to grow slowly and produce relatively  
36 few young, leaving them especially susceptible to overexploitation (Simpfendorfer and Kyne,  
37 2009). Squalene is a natural polyunsaturated hydrocarbon compound ( $C_{30}H_{50}$ ) found in many  
38 living organisms that can be refined from shark liver oil. This compound (and its more stable,  
39 hydrogenated derivate, squalane) have shown genuine potential to contribute to human health, as  
40 an ingredient in vaccines and other pharmaceuticals and dietary supplements (Kim and  
41 Karadeniz, 2012).

42  
43 Many shark species, particularly deep-sea sharks, have relatively large livers (up to 20% of  
44 animal weight) which serve as a buoyancy control system and critical energy reserve  
45 (Vannuccini 1999; Abel and Grubbs 2020). A significant portion of liver weight is made up of

46 liver oil (10-70%; Nichols et al., 2001), and between 15 and 82% of liver oil is squalene (Deprez  
47 et al., 1990; Bakes & Nichols 1995). Although squalene is produced by a range of animals and  
48 plants, shark liver oil has historically been a preferred commercial source based on availability  
49 and high yields relative to most plant-derived sources.

50  
51 Squalene can be extracted directly from shark liver oil at high purity (>98%) in approximately 10  
52 hours, using a single distillation process in a vacuum at 200-230° C, a faster process producing  
53 greater yields than plant-based alternatives (Camin et al., 2010). Sealed and protected from  
54 oxygen and light, squalene has an approximately two-year shelf life, making stable rates of  
55 ongoing production important to availability (Camin et al., 2010). Plant-derived squalene can  
56 also be refined to a high level of purity for medical applications, and is made up of C<sub>30</sub>H<sub>50</sub>  
57 molecules chemically identical to those from shark-derived sources. Plant-derived squalene has  
58 been shown to perform comparably to shark-derived squalene as an ingredient in vaccine  
59 adjuvants (Brito et al. 2011). Accordingly, the FDA is agnostic on the source of squalene and the  
60 *Current Good Manufacturing Practice for Finished Pharmaceuticals* only requires that lots of  
61 C<sub>30</sub>H<sub>50</sub> be “tested for conformity with all appropriate written specifications for purity, strength,  
62 and quality” (2019). Chemical vendors listed on the NIH National Library of Medicine for  
63 squalene do not differentiate by squalene origin but instead identify the compound by Chemical  
64 Abstract Services (CAS) number 7683-64-9, meaning there are no legal or administrative  
65 barriers preventing a shift to plant-derived sources of squalene (National Center for  
66 Biotechnology Information, 2020).

67  
68 Shark-derived squalene is a popular ingredient in topical cosmetic formulas and lotions,  
69 generating a significant portion of global demand for shark liver oil (Lozano-Grande et al., 2018;  
70 Ducos et al., 2015). In recent years, however, consumers and non-profit organizations in the  
71 United States and Europe have exerted pressure on the cosmetics industry to transition to plant-  
72 derived squalene (Consumers unaware of... 2013; Shark Free). Independent testing by the French  
73 non-profit organization Bloom determined most beauty products (>90% of those tested) sold in  
74 Europe or the United States no longer contain shark-derived ingredients, although shark-derived  
75 squalene remains in common use in beauty products elsewhere (Ducos et al., 2015). More recent  
76 studies have demonstrated the presence of shark DNA, including from Threatened and  
77 Endangered species, in some US-sold beauty products as well (Cardeñosa et al., 2017;  
78 Cardeñosa, 2019).

### 79 80 ***1.1 Squalene in vaccines***

81  
82 Squalene is used as an adjuvant, a component of a vaccine that enhances efficacy by increasing  
83 human immune response and the potency of antigens, while promoting antigen transport into  
84 lymph nodes and uptake in the immune cells (Brito and O’Hagan, 2014). The inclusion of  
85 adjuvants also reduces the volume of antigen needed per vaccine dose through the process of  
86 “antigen sparing,” maximizing rates of vaccine production (Tang et al.. 2015; Schmidt et al.  
87 2016). Although the primary global demand for shark liver oil in recent years appears to be for  
88 use in cosmetics and lotions (Vannuccini 1999; Lozano-Grande et al., 2018), the role of shark-  
89 derived squalene in vaccine production may represent a potential threat to some vulnerable shark  
90 populations, given widespread efforts to rapidly develop and disseminate vaccines in response to

91 the COVID-19 pandemic and the patchwork management approach to global shark fishing limits  
92 (Ahn et al., 2020; Hodgson, 2020; Davidson et al. 2016).

93

94 As an ingredient in adjuvants, squalene has been found to be safe and effective in vaccines for  
95 the treatment of viruses including H7N9 and H7N7 (Wu et al., 2014), H1N1 (Vesikari et al.,  
96 2012), MERS-CoV (Zhang et al. 2016), and SARS-CoV (Stadler et al., 2005). MF59, an  
97 adjuvant containing shark-derived squalene, has been used commercially in influenza vaccines  
98 (Schultze et al. 2008; Panatto et al. 2020) and used or tested in previous vaccines for other  
99 coronaviruses (Stadler et al., 2005; Zhang et al., 2016).

100

101 A few of the potential SARS-CoV-2 vaccines currently in testing include adjuvants MF59 or  
102 AS03, which are known to contain shark-derived squalene (COVID-19 Update 2020;  
103 GlaxoSmithKline aims... 2020, WHO, 2020). Per dose, MF59 contains 9.75 mg and AS03  
104 contains 10.68 mg of squalene (Jackson et al., 2015). Some potential vaccines are being  
105 manufactured in bulk before the completion of large-scale safety and efficacy trials (U.S. to  
106 Stockpile... 2020), suggesting that the total number of manufactured doses of various potential  
107 vaccines may be far higher than the number ultimately administered. It also remains unknown  
108 how frequently revaccination would be necessary if a safe and effective vaccine becomes  
109 available (COVID-19 Could Become... 2020; Ellis, 2020; Vaccine companies... 2020), so the  
110 scale of possible future demand for squalene as an ingredient in vaccine adjuvants is large but  
111 difficult to fully or accurately assess.

112

113 Deep-sea sharks are valued in the shark liver oil trade because they offer greater volumes of liver  
114 oil than other species. Relatively little is known about population structure, reproduction, and  
115 habitat use of many of these species due to the logistical difficulties of conducting research in  
116 deep-sea habitats and a generally low research and management priority (e.g., Neiva et al., 2006;  
117 Kyne and Simpfendorfer, 2007; Veríssimo et al., 2011). Most elasmobranchs are slow to mature  
118 and reproduce, and deep-sea sharks are particularly so, showing population increase rates of less  
119 than half those of continental shelf and pelagic shark species relying on shallower habitats  
120 (Simpfendorfer and Kyne, 2009). Squaloid sharks (species found in order squaliformes) are a  
121 preferred source of liver oil and squalene, and include species which are among the slowest  
122 growing and latest maturing sharks known (Musick, 2005). Shark reproductive rates and  
123 recovery potential generally decline with increasing depth, and overfished populations of deep-  
124 sea shark species may require centuries to recover (Simpfendorfer and Kyne, 2009). Evidence  
125 suggests that even low rates of deep-sea shark exploitation (incidental or targeted) is likely to  
126 quickly deplete populations (Simpfendorfer and Kyne, 2009). For these reasons, deep-sea sharks  
127 have been identified as a conservation priority grouping (Dulvy et al., 2014).

128

129 Assessment of the global conservation status of sharks is complicated by poor catch reporting,  
130 challenges with species-level identification, and a lack of baseline data. The reported annual  
131 catch of sharks likely substantially underestimates actual total catch (Worm et al., 2013; Dulvy et  
132 al., 2014). Total catch has been estimated at approximately 100 million animals annually, with an  
133 estimate range of 63 to 273 million (Worm et al., 2013). It is particularly difficult to assess rates  
134 of capture for species targeted for products like shark liver oil, for which there is relatively little  
135 detailed production or trade information available (Fowler et al., 1997; Vannuccini, 1999).

136

137 The global trade in shark liver oil is small compared to that in shark fins or meat, and despite the  
138 vulnerability of some target species to overfishing has received relatively little media (Shiffman  
139 et al., 2020) or scientific attention (Dent and Clarke, 2015). Although there are fisheries in which  
140 deep-sea sharks are targeted (see, e.g., Simpfendorfer and Kyne, 2007), liver oil may also be  
141 generated opportunistically from incidental catches in fisheries predominantly targeting other  
142 fish, or targeting sharks for other products (e.g., meat, fins). In at least some cases, however, the  
143 export value of shark liver oil exceeds that of shark meat, and in some locales the available  
144 supply of shark liver oil is insufficient to meet processors' demand for raw materials (Dent and  
145 Clarke, 2015). A lack of traceability presents a further challenge in assessing the trade in shark  
146 liver oil, as the United Nations Food and Agriculture Organization (FAO)'s *Codex Alimentarius*  
147 allows for products like squalene to be labelled as originating in the countries in which they were  
148 processed even when ingredients (e.g., the liver oil from which the squalene was derived) were  
149 produced elsewhere (FAO, 2001).

150

151 This study provides a basis for beginning to evaluate the range of potential conservation effects  
152 of increasing demand for shark-derived squalene as an ingredient in vaccine adjuvants.

153

## 154 **2. Materials and methods**

155

156 Based on a review of available scientific and management literature, 133 species were identified  
157 which are known to be involved in the liver oil trade (Appendix 1), including many that are  
158 partially reliant on deep-sea habitat >200 m (n=83) or are found exclusively in the deep-sea  
159 (n=21). Additional data on the conservation status and population trends of elasmobranch  
160 species, primarily sharks, identified as being involved in the liver oil trade were compiled from  
161 their most recent IUCN Red List assessments. Available current trade data on the shark liver oil  
162 trade was downloaded from the UN FAO FishStat Database (FAO, 2020). Commercial sources  
163 of wholesale quantities of squalene were identified through internet searches and through direct  
164 contact with wholesalers to collect pricing, origin, and availability information for both plant-  
165 and shark-derived squalene and squalane (its more stable, hydrogenated derivate).

166

## 167 **3. Results**

168

169 Across elasmobranch species identified as being exploited for shark liver oil, 50% had not been  
170 assessed by the IUCN in at least ten years, and 30% were considered Data Deficient (Figure 1;  
171 an IUCN Shark Specialist Group reassessment of elasmobranch species is currently underway  
172 and expected to be completed in 2020 (Dulvy, 2018)). One-third of species identified as part of  
173 the shark liver oil trade are classified as threatened (Vulnerable, Endangered, or Critically  
174 Endangered) according to IUCN Red List criteria (Figure 2). Population trends for 56% of these  
175 species are unknown, and 34% are assessed as showing a decreasing trend (Figure 3).

176

177 The most recent FAO data available (2018) showed an increase in reported import and processed  
178 production of shark liver oil, with trade volumes reaching 752 tons, the largest reported volume  
179 in decades (Figure 4; from 2000-2017, average reported trade volume was under 200 tons  
180 annually; Hareide et al., 2007). Despite this increase, the total value of the shark liver oil trade  
181 was reported at 553 000 USD in 2018, the lowest value reported since 1987 (mean annual value  
182 from 2000-2017, 1 954 000 USD; Hareide et al. 2007; FAO, 2020). Moderate assumptions about

183 oil yield suggest the range of individual animals in the reported global liver oil trade in 2018 falls  
184 between 694 848 (large sharks) and 16.35 million (small sharks), with 1.8 million (based on a  
185 20.8 kg median unidentified shark weight; Worm et al. 2013) as the best supported rough  
186 estimate (for yield assumptions see Table 1).

187  
188 Data collected on the price of shark- and plant-derived squalene showed no clear differences,  
189 though products listed as both shark- and plant-derived were commonly available in the  
190 wholesale market (Table 2). There was significant variability in price across individual sellers  
191 (ranging from \$20-260/kg for squalene and \$10-99.21/kg for squalane). The mean and median  
192 price for plant-derived squalene was \$40, and the mean price for shark-derived squalene was  
193 \$45.75 with a median of \$48.5/kg (excluding the outlier of \$260; including it, the mean price for  
194 shark-derived squalene was \$76.36, with a median price of \$54). The mean price for plant-  
195 derived squalane was \$53.16/kg (median \$48.65/kg), while shark-derived squalane was \$45/kg  
196 (median \$45/kg). These products were identified as being sold from China (67% of products)  
197 and the United States (33% of products). Based on these numbers, the estimated potential  
198 commercial value of squalene from a single shark ranges from \$0.05 (small shark/low yield) to  
199 \$242.65 (large shark/high yield).

200  
201 Given that each vaccine dose requires approximately 10mg of squalene, the mean squalene cost-  
202 per-vaccine-dose for shark-derived squalene would be \$0.0004575 USD, and for plant-derived,  
203 \$0.0004 USD—a price difference of \$0.0000575 per dose.

204

#### 205 **4. Discussion**

206

207 These results highlight the extent to which liver oil fisheries could affect shark species of  
208 conservation concern, and the potential difficulty of detecting these effects because of a lack of  
209 information on the volume of liver-oil-associated catch and the absence of population status  
210 information for many deep-sea species. The life history characteristics of deep-sea sharks  
211 (Simpfendorfer and Kyne, 2009), insufficient restrictions on exploitation, and declines in  
212 availability of shark-derived squalene over time (Sibuyo et al., 2017) suggest that the trade in  
213 shark liver oil, while currently small, has potential to disproportionately harm specific vulnerable  
214 elasmobranch species and populations.

215

216 Estimating potential conservation effects is further complicated by the fact that shark species  
217 vary greatly in the percentage of their body weight comprised of the liver (from at least 2.9-20%;  
218 Vannucini, 1999; Abel and Grubbs, 2020); in the amount of liver weight made up of oil (ranging  
219 from at least 10-70%; Nichols et al., 2001); and in the yield of squalene from extracted liver oil  
220 (a range of at least 15-82%; Deprez et al., 1990; Bakes & Nichols 1995). Evidence further  
221 suggests animal size, sex, and seasonal and regional factors can also affect yields (Kreuzer and  
222 Ahmed, 1978; Nichols et al., 2001). Accordingly, it is impossible to calculate an exact effect of  
223 increased vaccine-related demand for shark-derived squalene on shark populations.

224

225 We know that fisheries primarily targeting sharks for liver oil exist (e.g., Kyne and  
226 Simpfendorfer, 2007), and that, in many cases, multiple products may be marketed from a single  
227 shark (e.g., meat, fins, liver oil, cartilage). Data are not available to assess the volume of liver oil  
228 generated globally by directed versus incidental fishing. The effect of increased demand for

229 shark-derived squalene is highly dependent on whether it increases targeting of oil-rich deep-sea  
230 sharks, or simply drives increased processing and use of the livers of sharks currently taken for  
231 other purposes. Thus, conservation effects of vaccine-related demand for squalene could range  
232 from minimal (assuming demand is met by more efficient use of individuals already being  
233 landed in well-managed fisheries) to catastrophic for individual species (if demand drives the  
234 creation of new targeted fisheries for vulnerable deep-sea species in the absence of limits on  
235 fishing and trade).

236  
237 The future availability of shark squalene will likely be constrained by shark population declines  
238 and by regulatory efforts to conserve sharks, suggesting the prudence of shifting to more stable  
239 and sustainable sources. A vaccine supply chain dependent on shark fisheries is subject to  
240 disruption if targeted shark populations collapse or new protections are introduced.

241 Plant-derived alternatives to shark-derived squalene are more environmentally sustainable and  
242 readily available. Although in the past shark-derived squalene was reported to be significantly  
243 less expensive than plant-derived (Camin et al., 2010), current costs are similar. Non-animal-  
244 derived squalene may even be safer for use in some health-related applications because of the  
245 reduced risk of contamination with persistent organic pollutants, including polychlorinated  
246 biphenyls and organochlorine insecticides, high levels of which have been found in nutritional  
247 supplements made from shark liver oil (Rawn et al., 2009).

248  
249 Despite generally comparable costs between shark- and plant-derived squalene, and potential  
250 advantages in long-term availability and contaminant levels, non-animal-derived squalene does  
251 not appear to be in current use in vaccine production. Consumer and activist pressure could be  
252 effective in encouraging pharmaceutical companies to transition to non-animal-derived squalene  
253 in adjuvants, for testing for other medical uses, and in nutraceutical products. Demand-driven  
254 increases in production of pharmaceutical grade plant-derived alternatives may also incidentally  
255 support reduction or elimination of shark-derived squalene in cosmetic formulations. Increased  
256 accountability, including product testing to confirm plant origins and transparency within supply  
257 chains, would be vital to a transition away from reliance on shark-derived squalene.

258

## 259 **5. Conclusion**

260

261 The mean difference in cost per dose of a potential SARS-CoV-2 vaccine containing squalene  
262 derived from plants instead of shark liver oil is -\$0.0000575, based on currently available  
263 wholesale price information. While commercially available wholesale squalene may not meet the  
264 standard of purity needed for pharmaceutical applications, given these values it would cost  
265 \$20,125.00 less to generate the 350 million doses needed to vaccinate the U.S. population with  
266 plant- rather than shark-derived squalene. Doing the same for the global population of 7 billion  
267 would save \$402,500.00 over use of shark-derived squalene (without accounting for the effects  
268 high demand might have on price or availability).

269

270 In addition to similarities in cost, plant-derived sources of squalene have been shown to work  
271 comparably as an ingredient in adjuvants, and should not require a new approval process for use  
272 because they are chemically identical. Therefore, a shift to non-animal-derived squalene is highly  
273 feasible without disrupting efforts to rapidly develop a vaccine. A coordinated commitment by

274 the medical sector to transition to non-animal-derived squalene would support both  
275 environmental sustainability and public health goals.

276

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Table 1

Estimated number of sharks needed to produce two vaccine doses for the global human population under a range of yield assumptions.

Shark weight (kg)	Liver weight	Liver oil weight	Squalene weight	Total sharks*
	<u>20%</u>	<u>70%</u>	<u>82%</u>	
2.3 kg (small shark)	0.46	0.32	0.26	576,049
5.6 kg (deep-sea shark)	1.12	0.78	0.64	236,592
20.8 kg shark (median)	4.16	2.91	2.39	63, 693
46.2 kg (large shark)	9.24	6.47	5.30	28,678
	Moderate case			
	<u>10%</u>	<u>40%</u>	<u>50%</u>	
2.3 kg (small shark)	0.23	0.09	0.05	3,306,522
20.8 kg shark (median)	2.08	0.83	0.42	365,385
46.2 kg (large shark)	4.62	1.85	0.92	164,610
	Worst case			
	<u>3%</u>	<u>10%</u>	<u>15%</u>	
2.3 kg (small shark)	0.069	0.007	0.00104	146,956,522
20.8 kg shark (median)	0.624	0.062	0.00936	16,239,316
46.2 kg (large shark)	1.386	0.139	0.02079	7,316,017

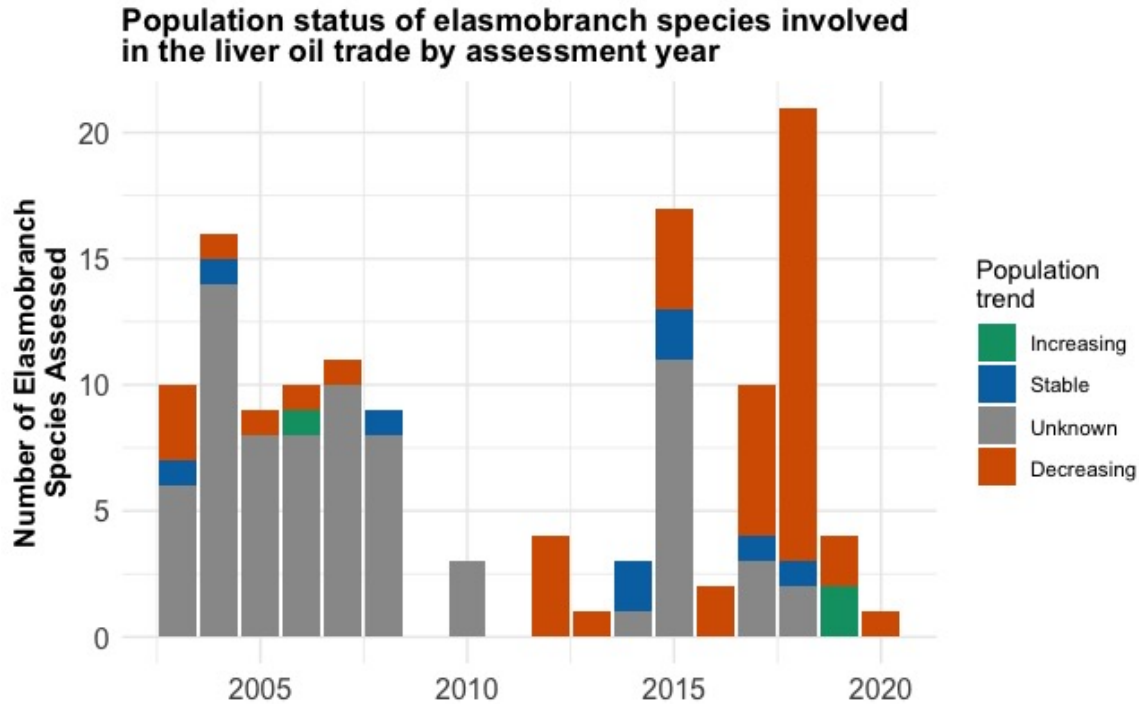
\* Based on a maximum demand estimate, assuming use of MF59 adjuvant containing 9.75 mg of squalene per dose to provide 2 vaccines to 7.8 billion people, total squalene demand for vaccines (drawn from existing or new fisheries) would be 152,100 kg.

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Table 2

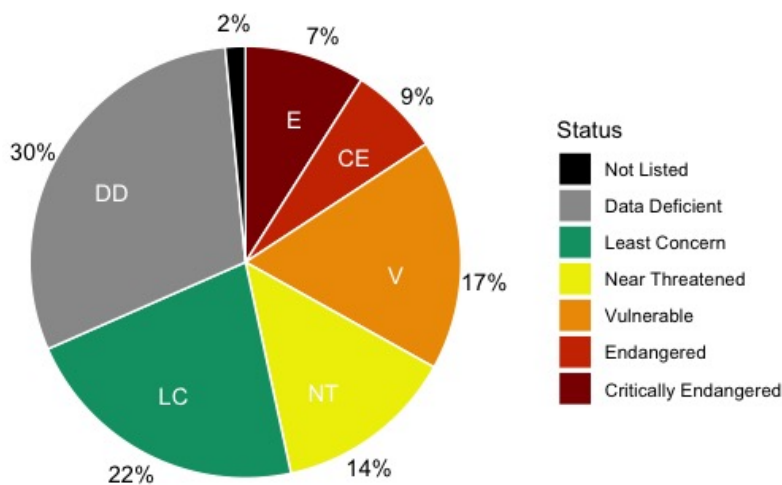
Current listed wholesale prices of shark- and plant-derived squalene and squalane by kg in USD.

<u>Squalene</u>			
<u>Source</u>	<u>Price/Kg (USD)</u>	<u>Sold From</u>	<u>Manufacturer</u>
Shark	\$39-47	China	Xi'an Rozen Biotechnology Co., Ltd
Shark	\$25	China	Xa Bc-Biotech Co., Ltd
Shark	\$54	China	Wuhan Hengheda Pharm Co., Ltd
Shark	\$260	China	Haihang Industry Co., Ltd
Shark	\$35-80	China	Xi'an Sheerherb Biological Technology
Shark	\$20-60	China	Shandong Zesheng Chemical Co., Ltd
Shark	\$55	China	Shaanxi Phoenix Tree Biotech Co., Ltd
Olive Oil	\$20-60	China	Suzhou Manson Biotech Co., Ltd
Soybeans	\$20-60	China	Suzhou Manson Biotech Co., Ltd
<u>Squalane</u>			
<u>Source</u>	<u>Price/Kg (USD)</u>	<u>Sold From</u>	<u>Manufacturer</u>
Shark	~\$40	USA	Jedwards International INC.
Shark	\$50	China	Xa Bc-Biotech Co, Ltd
Olive Oil	\$44.89	USA	Cocojojo Beauty
Olive Oil	\$63.99	USA	Organic Gold
Olive Oil	\$10-20	China	Shandong Zhonglan Chemical Co., Ltd
Olive Oil	\$40-60	China	Xi'an Geekee Biotech Co., Ltd
Olive Oil	~\$51.75	USA	Jedwards International INC.
Olive Oil	~\$47.30	USA (Origin Italy, Spain)	Blossom Bulk Ingredients
Neossance (Sugarcane)	\$99.21	USA	HBNO



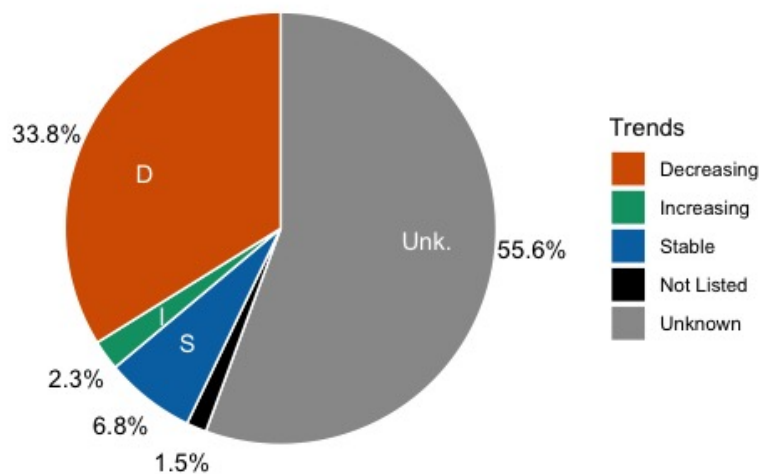
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488 **Figure 1.** Most recent IUCN Red List assessments for assessed elasmobranch species (n=131)  
489 reported in the liver oil trade. The earliest assessment of a species identified as traded for liver oil  
490 took place in 2003.  
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### Conservation Status of Elasmobranchs Used for the Squalene and Liver Oil Industries



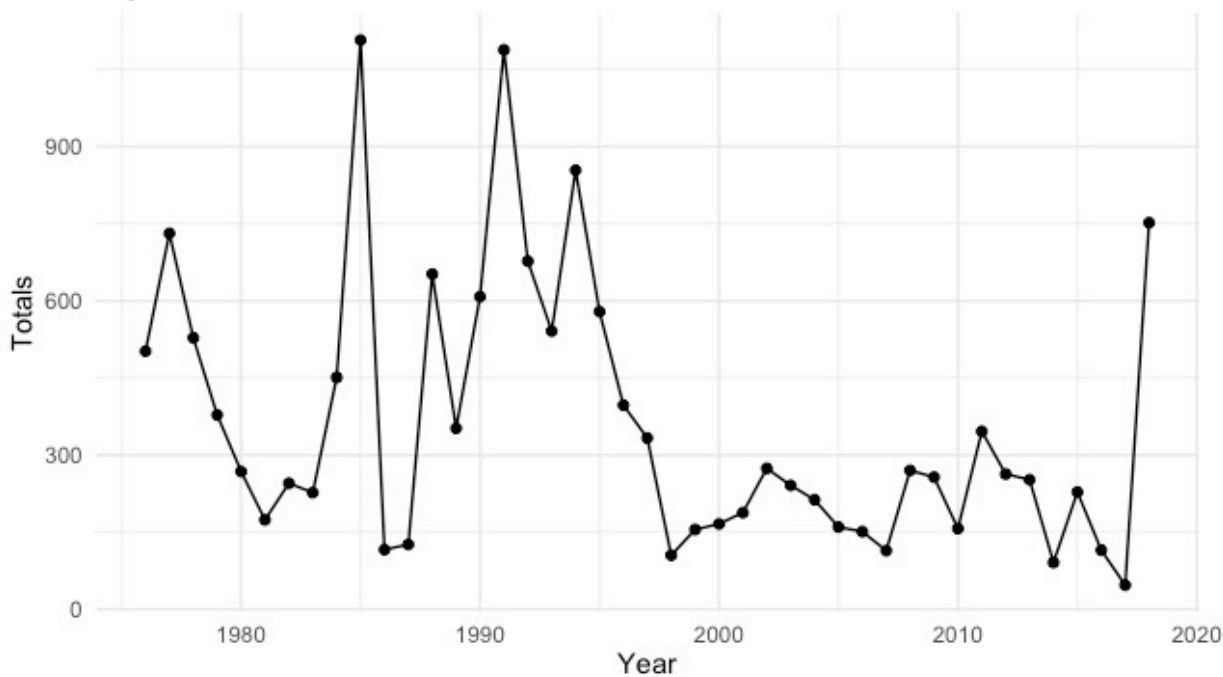
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493 **Figure 2.** IUCN Red List conservation status of elasmobranch species reported in the liver oil  
494 trade.  
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### Population Trends of Elasmobranch Species Used in the Squalene and Liver Oil Industries



496  
497 **Figure 3.** IUCN Red List population trends of all elasmobranch species reported in the liver oil  
498 trade.  
499

### Total Net Weight (tonnes) per year of shark liver oil trade reported to FAO



500  
501 **Figure 4.** The total reported net weight (tonnes) of annual trade in shark liver oil reported to  
502 FAO. In 2018, two countries reported trade: imports of 33 tonnes (Republic of Korea) and  
503 processed production of 719 tonnes (Senegal).



504 Appendix A: Elasmobranchs reported to be used in the liver oil and squalene trades, including  
 505 IUCN conservation status and population trend assessment information.

506  
 507 Table A.1  
 508

Scientific Name	Family Name	Common Name	Source	IUCN Conservation Status	IUCN Assessed Population Trend	Year Last Assessed
<i>Alopias pelagicus</i>	Alopiidae	Pelagic Thresher	Vannuccini 1999	EN	Decreasing	2018
<i>Alopias superciliosus</i>	Alopiidae	Bigeye Thresher	Vannuccini 1999	VU	Decreasing	2018
<i>Alopias vulpinas</i>	Alopiidae	Common Thresher	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2018
<i>Anoxypristis cuspidata</i>	Pristidae	Knifetooth Sawfish/Narrow Sawfish	Fowler et al., 1997	EN	Decreasing	2012
<i>Atelomycterus baliensis</i>	Scyliorhinidae	Bali Catshark	Fowler et al., 1997	VU	Unknown	2008
<i>Atelomycterus fasciatus</i>	Scyliorhinidae	Banded Catshark	Fowler et al., 1997	LC	Unknown	2015
<i>Atelomycterus macleayi</i>	Scyliorhinidae	Australian Marbled Catshark	Fowler et al., 1997	LC	Unknown	2015
<i>Atelomycterus marmoratus</i>	Scyliorhinidae	Coral Catshark	Fowler et al., 1997	NT	Unknown	2003
<i>Atelomycterus marnkalha</i>	Scyliorhinidae	Eastern Banded Catshark	Fowler et al., 1997	DD	Unknown	2015
<i>Aulohalaelurus kanakorum</i>	Scyliorhinidae	New Caledonia Catshark	Fowler et al., 1997	DD	Unknown	2017
<i>Aulohalaelurus labiosus</i>	Scyliorhinidae	Black Spotted Catshark	Fowler et al., 1997	LC	Unknown	2015
<i>Carcharhinus albimarginatus</i>	Carcharhinidae	Silvertip Shark	Vannuccini 1999	VU	Decreasing	2015
<i>Carcharhinus altimus</i>	Carcharhinidae	Bignose Shark	Fowler et al., 1997; Vannuccini 1999	DD	Unknown	2008
<i>Carcharhinus amblyrhynchos</i>	Carcharhinidae	Grey Reef Shark	Vannuccini 1999	NT	Unknown	2005
<i>Carcharhinus brevipinna</i>	Carcharhinidae	Spinner Shark	Fowler et al., 1997;	NT	Unknown	2005

			Vannuccini 1999			
<i>Carcharhinus falciformis</i>	Carcharhinidae	Silky Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2017
<i>Carcharhinus leucas</i>	Carcharhinidae	Bull Shark	Fowler et al., 1997; Vannuccini 1999	NT	Unknown	2005
<i>Carcharhinus limbatus</i>	Carcharhinidae	Blacktip Shark	Fowler et al., 1997; Vannuccini 1999	NT	Unknown	2005
<i>Carcharhinus longimanus</i>	Carcharhinidae	Oceanic Whitetip Shark	Fowler et al., 1997; Vannuccini 1999	CR	Decreasing	2018
<i>Carcharhinus melanopterus</i>	Carcharhinidae	Blacktip Reef Shark	Fowler et al., 1997; Vannuccini 1999	NT	Decreasing	2005
<i>Carcharhinus obscurus</i>	Carcharhinidae	Dusky Shark	Fowler et al., 1997; Vannuccini 1999	EN	Decreasing	2018
<i>Carcharhinus plumbeus</i>	Carcharhinidae	Sandbar Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2007
<i>Carcharias taurus</i>	Odontaspidae	Sand Tiger Shark	Fowler et al., 1997; Vannuccini 1999	CR	Decreasing	2016
<i>Carcharodon carcharias</i>	Lamnidae	White Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2018
<i>Centrophorus acus</i>	Centrophoridae	Needle Dogfish	Fowler et al., 1997; Vannuccini 1999	Not Listed	Not Listed	Not Listed
<i>Centrophorus lusitanicus</i>	Centrophoridae	Lowfin Gulper Shark	Fowler et al., 1997; Vannuccini 1999	VU	Unknown	2008
<i>Centrophorus niaukang</i>	Centrophoridae	Taiwan Gulper Shark	Fowler et al., 1997	Not Listed	Not Listed	Not Listed

<i>Centrophorus squamosus</i>	Centrophoridae	Leafscale Gulper Shark	Fowler et al., 1997;; Vannuccini 1999	VU	Decreasing	2003
<i>Centroselachus crepidater</i>	Somniosidae	Longnose Velvet Dogfish	Fowler et al., 1997; Vannuccini 1999	LC	Unknown	2003
<i>Cephaloscyllium albipinnum</i>	Scyliorhinidae	Whitefin Swellshark	Fowler et al., 1997	CR	Decreasing	2018
<i>Cephaloscyllium cooki</i>	Scyliorhinidae	Cook's Swellshark	Fowler et al., 1997	DD	Unknown	2015
<i>Cephaloscyllium fasciatum</i>	Scyliorhinidae	Reticulated Swellshark	Fowler et al., 1997	DD	Unknown	2010
<i>Cephaloscyllium hiscosellum</i>	Scyliorhinidae	Reticulate Swellshark	Fowler et al., 1997	LC	Unknown	2015
<i>Cephaloscyllium isabellum</i>	Scyliorhinidae	Carpet Shark	Fowler et al., 1997	LC	Stable	2017
<i>Cephaloscyllium laticeps</i>	Scyliorhinidae	Australian Swellshark	Fowler et al., 1997	LC	Stable	2015
<i>Cephaloscyllium maculatum</i>	Scyliorhinidae	Spotted Swellshark	Fowler et al., 1997	DD	Unknown	2010
<i>Cephaloscyllium pardelotum</i>	Scyliorhinidae	Leopard-spotted Swellshark	Fowler et al., 1997	DD	Unknown	2010
<i>Cephaloscyllium sarawakensis</i>	Scyliorhinidae	Sarawak Pygmy Swell Shark	Fowler et al., 1997	DD	Unknown	2008
<i>Cephaloscyllium signourum</i>	Scyliorhinidae	Flagtail Swellshark	Fowler et al., 1997	DD	Unknown	2015
<i>Cephaloscyllium silasi</i>	Scyliorhinidae	Indian Swellshark	Fowler et al., 1997	DD	Unknown	2008
<i>Cephaloscyllium speccum</i>	Scyliorhinidae	Speckled Swellshark	Fowler et al., 1997	DD	Unknown	2015
<i>Cephaloscyllium sufflans</i>	Scyliorhinidae	Balloon Shark	Fowler et al., 1997	NT	Decreasing	2019
<i>Cephaloscyllium umbratile</i>	Scyliorhinidae	Japanese Swellshark	Fowler et al., 1997	DD	Unknown	2007
<i>Cephaloscyllium variegatum</i>	Scyliorhinidae	Saddled Swellshark	Fowler et al., 1997	NT	Decreasing	2018
<i>Cephaloscyllium ventriosum</i>	Scyliorhinidae	Swell Shark	Fowler et al., 1997	LC	Unknown	2015

<i>Cephaloscyllium zebrium</i>	Scyliorhinidae	Narrowbar Swellshark	Fowler et al., 1997	DD	Unknown	2015
<i>Cetorhinus maximus</i>	Cetorhinidae	Basking Shark	Fowler et al., 1997; Vannuccini 1999	EN	Decreasing	2018
<i>Cirrhigaleus asper</i>	Squalidae	Roughskin Shark/Roughsk in Spurdog	Fowler et al., 1997; Vannuccini 1999	VU	Unknown	2017
<i>Cirrhigaleus barbifer</i>	Squalidae	Mandarin Dogfish	Fowler et al., 1997; Vannuccini 1999	DD	Unknown	2007
<i>Dalatias licha</i>	Dalatiidae	Kitefin Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2017
<i>Dasyatis pastinaca</i>	Dasyatidae	Common Stingray	Vannuccini 1999	DD	Unknown	2003
<i>Deania calcea</i>	Centrophoridae	Birdbeak Dogfish	Fowler et al., 1997; Vannuccini 1999	LC	Unknown	2003
<i>Echinorhinus brucus</i>	Echinorhinidae	Bramble Shark	Fowler et al., 1997; Vannuccini 1999	DD	Unknown	2003
<i>Eusphyra blochii</i>	Sphyrnidae	Winghead Shark	Fowler et al., 1997	EN	Decreasing	2015
<i>Galeocerdo cuvier</i>	Carcharhinidae	Tiger Shark	Fowler et al., 1997; Vannuccini 1999	NT	Decreasing	2018
<i>Galeorhinus galeus</i>	Triakidae	Tope Shark	Fowler et al., 1997; Vannuccini 1999	CR	Decreasing	2020
<i>Galeus antillensis</i>	Pentanchidae	Antilles Catshark	Vannuccini 1999	DD	Unknown	2004
<i>Galeus arae</i>	Pentanchidae	Roughtail Catshark	Vannuccini 1999	LC	Unknown	2004
<i>Galeus atlanticus</i>	Pentanchidae	Atlantic Sawtail Catshark	Vannuccini 1999	NT	Unknown	2007
<i>Galeus cadenati</i>	Pentanchidae	Longfin Sawtail Catshark	Vannuccini 1999	DD	Unknown	2004

<i>Galeus eastmani</i>	Pentanchidae	Gecko Catshark	Vannuccini 1999	LC	Unknown	2007
<i>Galeus gracilis</i>	Pentanchidae	Slender Sawtail Shark	Vannuccini 1999	DD	Unknown	2015
<i>Galeus longirostris</i>	Pentanchidae	Longnose Sawtail Catshark	Vannuccini 1999	DD	Unknown	2007
<i>Galeus melastomus</i>	Pentanchidae	Blackmouth Catshark	Vannuccini 1999	LC	Stable	2003
<i>Galeus mincaronei</i>	Pentanchidae	Southern Sawtail Catshark	Vannuccini 1999	VU	Decreasing	2004
<i>Galeus murinus</i>	Pentanchidae	Mouse Catshark	Vannuccini 1999	LC	Stable	2014
<i>Galeus nipponensis</i>	Pentanchidae	Broadfin Sawtail Catshark	Vannuccini 1999	DD	Unknown	2008
<i>Galeus piperatus</i>	Pentanchidae	Peppered Catshark	Vannuccini 1999	LC	Unknown	2006
<i>Galeus polli</i>	Pentanchidae	Galeus polli	Vannuccini 1999	LC	Stable	2004
<i>Galeus priapus</i>	Pentanchidae	Phallic Catshark	Vannuccini 1999	LC	Unknown	2017
<i>Galeus sauteri</i>	Pentanchidae	Blacktip Sawtail Catshark	Vannuccini 1999	DD	Unknown	2007
<i>Galeus shcultzi</i>	Pentanchidae	Dwarf Sawtail Catshark	Vannuccini 1999	DD	Unknown	2007
<i>Galeus springeri</i>	Pentanchidae	Galeus springeri	Vannuccini 1999	DD	Unknown	2004
<i>Glaucostegus typus</i>	Glaucostegidae	Giant Guitarfish	Vannuccini 1999	CR	Decreasing	2018
<i>Hemipristis elongata</i>	Hemigaleidae	Snaggletooth Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2015
<i>Hexanchus griseus</i>	Hexanchidae	Bluntnose Sixgill Shark	Fowler et al., 1997; Vannuccini 1999	NT	Unknown	2005
<i>Isurus oxyrinchus</i>	Lamnidae	Shortfin Mako	Fowler et al., 1997; Vannuccini 1999	EN	Decreasing	2018
<i>Isurus paucus</i>	Lamnidae	Longfin Mako	Fowler et al., 1997;	EN	Decreasing	2018

			Vannuccini 1999			
<i>Lamna ditropis</i>	Lamnidae	Salmon Shark	Fowler et al., 1997; Vannuccini 1999	LC	Stable	2018
<i>Lamna nasus</i>	Lamnidae	Porbeagle Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2018
<i>Mestelus manazo</i>	Triakidae	Starspotted Smoothhound	Fowler et al., 1997	DD	Unknown	2007
<i>Mustelus californicus</i>	Triakidae	Gray Smooth Hound	Vannuccini 1999	LC	Unknown	2014
<i>Mustelus griseus</i>	Triakidae	Spotless Smooth Hound	Vannuccini 1999	DD	Unknown	2007
<i>Nebrius ferrugineus</i>	Ginglymostomatidae	Tawny Nurse Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2003
<i>Negaprion acutidens</i>	Carcharhinidae	Sharptooth Lemon Shark/ Sicklefin Lemon Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2003
<i>Odontaspis ferox</i>	Odontaspidae	Smalltooth Sand Tiger Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2015
<i>Odontaspis noronhai</i>	Odontaspidae	Bigeye Sand Tiger Shark	Fowler et al., 1997	LC	Unknown	2018
<i>Poroderma africanum</i>	Scyliorhinidae	Pyjama Shark	Fowler et al., 1997	LC	Increasing	2019
<i>Poroderma pantherinum</i>	Scyliorhinidae	Leopard Catshark	Fowler et al., 1997	LC	Increasing	2019
<i>Prionace glauca</i>	Carcharhinidae	Blue Shark	Vannuccini 1999	NT	Decreasing	2018
<i>Pristiophorus nudipinnis</i>	Pristiophoridae	Southern Sawshark	Vannuccini 1999	LC	Stable	2015
<i>Pristis clavata</i>	Pristidae	Dwarf Sawfish	Fowler et al., 1997	EN	Decreasing	2012
<i>Pristis pectinata</i>	Pristidae	Smalltooth Sawfish/Wide Sawfish	Fowler et al., 1997	CR	Decreasing	2012

<i>Pristis pristis</i>	Pristidae	Large-tooth Sawfish	Fowler et al., 1997	CR	Decreasing	2013
<i>Pristis zijsron</i>	Pristidae	Longcomb Sawfish/Green Sawfish	Fowler et al., 1997	CR	Decreasing	2012
<i>Rhincodon typus</i>	Rhincodontidae	Whale Shark	Vannuccini 1999	EN	Decreasing	2016
<i>Schroederichthys biviuis</i>	Scyliorhinidae	Narrowmouth Catshark	Fowler et al., 1997	DD	Unknown	2005
<i>Schroederichthys chilensis</i>	Scyliorhinidae	Chilean Catshark	Fowler et al., 1997	DD	Unknown	2004
<i>Schroederichthys maculatus</i>	Scyliorhinidae	Narrowtail Catshark	Fowler et al., 1997	LC	Unknown	2004
<i>Schroederichthys saurisqualus</i>	Scyliorhinidae	Lizard Catshark	Fowler et al., 1997	VU	Unknown	2004
<i>Schroederichthys tenuis</i>	Scyliorhinidae	Slender Catshark	Fowler et al., 1997	DD	Unknown	2004
<i>Scyliorhinus besnardi</i>	Scyliorhinidae	Scyliorhinus besnardi	Fowler et al., 1997	DD	Unknown	2004
<i>Scyliorhinus boa</i>	Scyliorhinidae	Boa Catshark	Fowler et al., 1997	LC	Unknown	2004
<i>Scyliorhinus canicula</i>	Scyliorhinidae	Small Spotted Cat Shark	Fowler et al., 1997	LC	Stable	2008
<i>Scyliorhinus capensis</i>	Scyliorhinidae	Yellow Spotted Catshark	Fowler et al., 1997	NT	Decreasing	2019
<i>Scyliorhinus cervigoni</i>	Scyliorhinidae	Scyliorhinus cervigoni	Fowler et al., 1997	DD	Unknown	2006
<i>Scyliorhinus comoroensis</i>	Scyliorhinidae	Comoro Catshark	Fowler et al., 1997	DD	Unknown	2018
<i>Scyliorhinus garmani</i>	Scyliorhinidae	Brownspotted Catshark	Fowler et al., 1997	DD	Unknown	2007
<i>Scyliorhinus haecklii</i>	Scyliorhinidae	Scyliorhinus haecklii	Fowler et al., 1997	DD	Unknown	2004
<i>Scyliorhinus hesperius</i>	Scyliorhinidae	Scyliorhinus hesperius	Fowler et al., 1997	DD	Unknown	2004
<i>Scyliorhinus meadi</i>	Scyliorhinidae	Scyliorhinus meadi	Fowler et al., 1997	DD	Unknown	2006
<i>Scyliorhinus retifer</i>	Scyliorhinidae	Scyliorhinus retifer	Fowler et al., 1997	LC	Increasing	2006
<i>Scyliorhinus stellaris</i>	Scyliorhinidae	Nursehound	Fowler et al., 1997	NT	Unknown	2006

<i>Scyliorhinus tokubee</i>	Scyliorhinidae	Izu Catshark	Fowler et al., 1997	DD	Unknown	2008
<i>Scyliorhinus torazame</i>	Scyliorhinidae	Cloudy Catshark	Fowler et al., 1997	LC	Unknown	2008
<i>Scyliorhinus torrei</i>	Scyliorhinidae	Dwarf Catshark	Fowler et al., 1997	LC	Unknown	2004
<i>Scymnodon plunketi</i>	Somniosidae	Plunket's Shark	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2017
<i>Somniosus microcephalus</i>	Somniosidae	Greenland Shark	Vannuccini 1999	NT	Unknown	2006
<i>Sphyrna corona</i>	Sphyrnidae	Scalloped Bonnethead	Vannuccini 1999	NT	Unknown	2004
<i>Sphyrna lewini</i>	Sphyrnidae	Scalloped Hammerhead	Vannuccini 1999	CR	Decreasing	2018
<i>Sphyrna media</i>	Sphyrnidae	Scoophead Shark	Vannuccini 1999	DD	Unknown	2006
<i>Sphyrna mokarran</i>	Sphyrnidae	Great Hammerhead	Vannuccini 1999	CR	Decreasing	2018
<i>Sphyrna tiburo</i>	Sphyrnidae	Bonnethead Shark	Vannuccini 1999	LC	Stable	2014
<i>Sphyrna tudes</i>	Sphyrnidae	Smalleye Hammerhead	Vannuccini 1999	VU	Decreasing	2006
<i>Sphyrna zygaena</i>	Sphyrnidae	Smooth Hammerhead	Fowler et al., 1997	VU	Decreasing	2018
<i>Squalus acanthias</i>	Squalidae	Piked Dogfish/Spiny Dogfish	Fowler et al., 1997; Vannuccini 1999	VU	Decreasing	2016
<i>Squalus cubensis</i>	Squalidae	Cuban Dogfish	Fowler et al., 1997; Vannuccini 1999	DD	Unknown	2006
<i>Squalus mitsukurii</i>	Squalidae	Shortspine spurdog	Fowler et al., 1997; Vannuccini 1999	DD	Unknown	2007
<i>Squatina aculeata</i>	Squatinae	Sawback Angelshark	Fowler et al., 1997; Vannuccini 1999	CR	Decreasing	2017
<i>Squatina oculata</i>	Squatinae	Smoothback Angelshark	Fowler et al., 1997	CR	Decreasing	2017



<i>Squatina squatina</i>	Squatinidae	Angelshark	Fowler et al., 1997	CR	Decreasing	2017
<i>Triaenodon obesus</i>	Carcharhinidae	Whitetip Reef Shark	Vannuccini 1999	NT	Unknown	2005

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